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HumRRO Studies in Continuous Operations

by

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HumRRO

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Prefatory Note

This paper was presented at the 15th Annual Army Human Factors Research and Development Conference, held at the U.S. Army Training Center, Infantry, in Fort Ord, California, in November 1969. Research for the paper was performed under Work Unit ENDURE, Tank Crew Performance During Periods of Extended Combat, at the Human Resources Research Organization, Division No. 2, in Fort Knox, Kentucky. Dr. Haggard is Director of HumRRO Division No. 2.

The paper was presented at the session of the conference titled, "Human Factors in Continuous Operations." The paper appears in the published proceedings of the conference.

HumRRO Studies in Continuous Operations

Donald F. Haggard

INTRODUCTION

The purpose of this paper is to present the results of the first two studies in a series conducted by the Human Resources Research Organization, concerned with the effects of continuous operations on performance. Our objective was to determine which tank crew tasks would show performance decrements during 48 hours of continuous combat-type operations, and to examine the degree of decrement in terms of its effect on tactical efficiency.

A second purpose of this paper is to illustrate the need for increased efficiency in obtaining this type of human factors information in the future—a level of efficiency that we hope to approach as a result of changes now in process within the Army's human factors system.

Military Problem

The increasing complexity of military tactics and equipment is placing major emphasis on evaluation of the human element as an integral part of the man-machine-tactical system. It has been estimated that human error accounts for 24% of present total system unreliability (1). This percentage can be expected to increase drastically as proposed tactics extend the conditions under which the human must operate and the use of new equipment requires a greater range and higher level of operational skill. As this occurs, the military planner is faced with the need for more and different human factors information to support his estimates of tactical capability and tactical requirements.

But such information is seldom available in the form that the military planner requires; too often, in fact, it is not available at all. In such situations, the planner must rely almost entirely on judgments based on past experience. These experiential judgments become more invalid as tactical conditions and hardware changes become more revolutionary. The military planner then is faced with the choice of operating with almost no valid information or of determining the necessary human factors parameters by costly field studies. This situation seems to apply to human endurance.

New military equipment capable of operating continuously for extended periods is being developed for the Army to meet the anticipated tactical requirements of the future battlefield. This increased capability will place stringent demands on the soldier who must operate the equipment.

To take advantage of these technological advances, the soldier must also be capable of sustained performance. If he is not, the effectiveness of the tactical system *may* be compromised enough to seriously endanger its success. A method would then have to be found to overcome the human decrement.

Research Problem

The research problem is (a) to specify the tasks for which performance decrements can be expected during extended periods of operation, the extent of the decrement, and the time at which it will occur; (b) to estimate the effect of the decrement on tactical success; and, finally, (c) if the decrement will be serious, to determine the possible cost/effectiveness alternatives of decreased tactical effectiveness as opposed to military doctrinal changes, hardware modification, personnel selection, or special operator training or conditioning programs. Only then is a solution to the military problem possible.

There are also some straightforward approaches to solving the problem. The most obvious approach might be the following:

(1) Specify the job model in which we are interested, the human tasks required, the conditions under which they must be performed, and the standard of human performance that was assumed when the tactic was formulated and without which the tactic will be unsuccessful.

(2) Determine the human capability of performing each task under the conditions specified; do so by extrapolation from the available literature and, if pertinent literature is not available, by developmental studies.

(3) Examine the effects on tactical success of any difference between the human performance standard and the established human performance capability, and,

(4) For serious differences between performance found and standard required, to calculate the alternatives involved in undertaking remedial action.

RESEARCH APPROACH

Our experience in attempting to apply this approach to one area, sustained performance of the tank crew, illustrates some of the needs of an effective and efficient human factors system for the Army.

First, to determine the job model we used a considerable number of available *task* analyses for the tank crew. The *condition* under which the tasks had to be performed was specified sufficiently by the mission narrative for the tactic and specifically by the endurance problem. However, nowhere in these tactical specifications was there an objective statement of the man-machine system standard required to make the tactic a success. Without the system standard, we could not calculate the required human performance capabilities. The problem was soon

reduced to determining which tasks could be expected to show a decrement during extended periods of operation, with only *judgments* of the impact of possible decrements on tactical success.

Next, with regard to human capability, an extensive search of both military records and psychological literature offered little information pertinent to the endurance condition (2). We can divide this literature into basic, developmental, and applied, (although previous attempts to categorize research on such a prestige-laden scale have been criticized). Our experience with the laboratory literature has been fairly well characterized by a number of recent reviews (e.g., 3, 4, 5, 6).

Chapanis (3) has summarized the faults found in these reviews as they deal with attempts to apply laboratory results to real-life situations: (a) Only a few independent variables are selected so that many important interactions may be excluded, (b) the character of the variables is often changed inside the laboratory, (c) experimental conditions are so well controlled that significant differences found in the laboratory are later found to be of no practical importance in the field, (d) the methods used to present variables are unrealistic, and (e) criteria are chosen for convenience rather than relevance. Thus he concluded that "one should generalize with extreme caution from the results of laboratory experiments to the solution of practical problems."

However, many of these same cautions can be applied to use of the results of developmental studies in solving practical problems. We found that endurance studies of task performance in both fairly realistic and simulated laboratory conditions presented conflicting results that could not be reconciled because different measures were taken after different periods of time. Also, whether the studies were basic, developmental, or applied, we had difficulty applying results to our particular problem without a basis for generalizing between even apparently similar tasks. Attempts to extrapolate to the tank crew problem without a task taxonomy were very tenuous.

Hence the results of the survey of human capability were extremely limited. They did, however, confirm some fairly well-known principles. (a) When little physical labor is required, crew tasks having high cognitive, perceptual, or perceptual-motor loadings will be susceptible to significant fatigue decrements from long-term operation. (b) The diurnal cycle will have a significant effect on performance. (c) Varying tasks through job rotation will lessen decrements only if the jobs include tasks with different human requirements.

While these findings may be well-known, they were in conflict with generally accepted military opinion which held that (a) men performed similar jobs, particularly during World War II, for much longer periods without any *perceived* performance decrements; (b) allowing men to sleep until just before a night operation overcomes any diurnal effects; and (c) job rotation within a cross-trained tank crew prevents endurance decrements.

Since a field study would be expensive, and replication over each of the indicated variables prohibitively so, it was decided to conduct a laboratory study, to determine whether large enough decrements would

occur in simulated crew tasks to justify a field study, and whether the effects of diurnal cycle and job rotation would be significant.

Study 1: Laboratory

One hundred-forty-two enlisted men trained as tank crewmen were assigned to four experimental groups (Table 1). Group conditions were varied so that comparisons of the performances of pairs of groups made

Table 1

Experimental Conditions for Study 1: Laboratory

Group	Sleep Deprivation	Starting Time	Job Rotation	*N*
I	Yes	2000	No	42
II	Yes	2000	Yes	40
III	Yes	0800	Yes	40
IV	No	2000	No	20

it possible to determine the effects of sleep deprivation (fatigue), starting time (diurnal cycle), and job rotation. The men worked in three groups for 48 hours with a 15-minute break after every 1½ hours of work and a one-hour meal break every six hours, but with no time provided specifically for sleep. Men in the fourth group performed according to the same schedule except during the night, when they were allowed to sleep. For three groups, the experiment began in the evening; for the fourth, in the morning. For two groups the men performed the same task throughout the experiment; for two groups, they rotated from one task to the other after each 1½ hour period.

Two tasks were studied: a surveillance task, thought to have high perceptual loading and to be required of the crew continuously; and a driving task, thought to have high perceptual-motor loading and to be required of the driver continuously. (A third task, assembly-disassembly of a machine gun, was included to provide data on continuous cognitive and periodic motor decrements. This task was not analyzed because of the significant interactions found with the mechanical condition of different guns.)

The surveillance task was simulated on a large screen upon which four terrain scenes were projected. The subject responded to a momentary light flash in one of the four scenes and the number of detections was measured. The driving task was simulated by a steering mechanism containing a tank steering wheel, a light source, and a moving belt that represented a winding pathway. Photocells behind the belt were activated by the light source when the men steered improperly, providing a measure of time-off-the-pathway.

The results (7) indicated that:

(1) Large performance decrements result from 48 hours of operation without sleep (for example, Figure 1).

Mean Driving Scores Obtained in Each Period Over 48 Hours by Groups I and IV

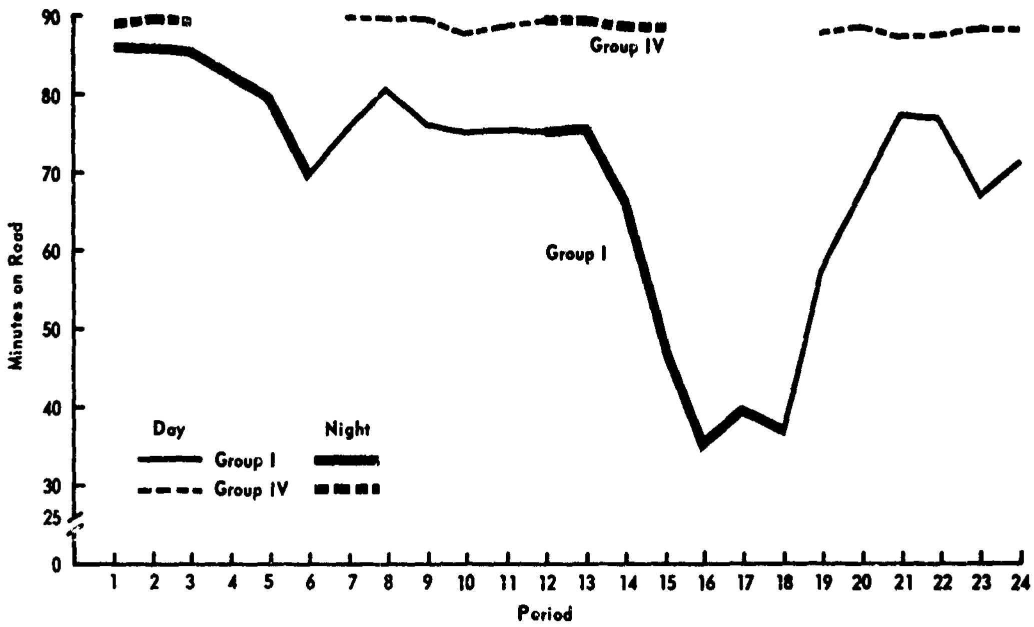

Figure 1

(2) Decrements occur primarily at night, especially during the second night of a 48-hour period (for example, Figure 2). However, during the second night the experimenters found it impossible to keep the men awake.

(3) Job rotation has mixed effects for the two tasks, possibly reducing the decrement in driving, which might induce unique muscular fatigue, but not reducing the decrement in surveillance (for example, Figure 3); for which perceptual requirements are similar to those of driving.

On this basis it was decided that a 48-hour field study was justified, and that it should provide repeated measures during both day and night operation (although for most tank crew tasks, night operation requires the use of flashlights, searchlights, flares, or infrared vision devices and is therefore substantially different from day operation). It was felt, however, that the cost of cross-training and varying starting times did not warrant replication. The problem was thus one of determining whether performance decrements similar to those found in the laboratory would be negated by the increased crew motivation expected in a field operation.

Mean Driving Scores Obtained in Each Combined Period Over 48 Hours by Groups II and III in Starting Time Comparison

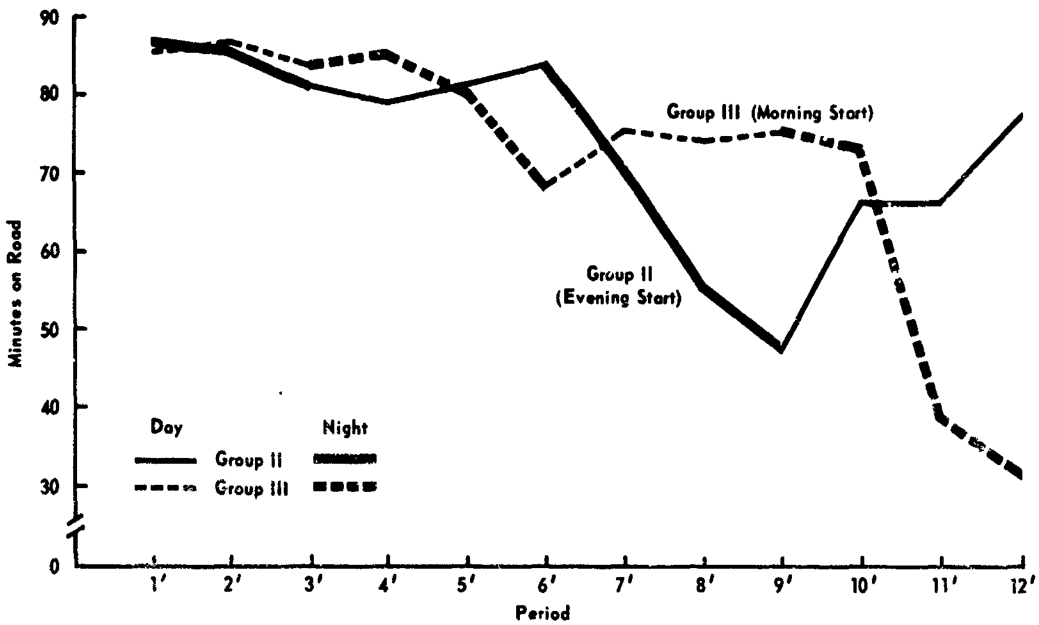

Figure 2

Mean Target Detection Scores Obtained Over 48 Hours in Odd-Numbered Periods by Groups I and II in Job Rotation Comparison

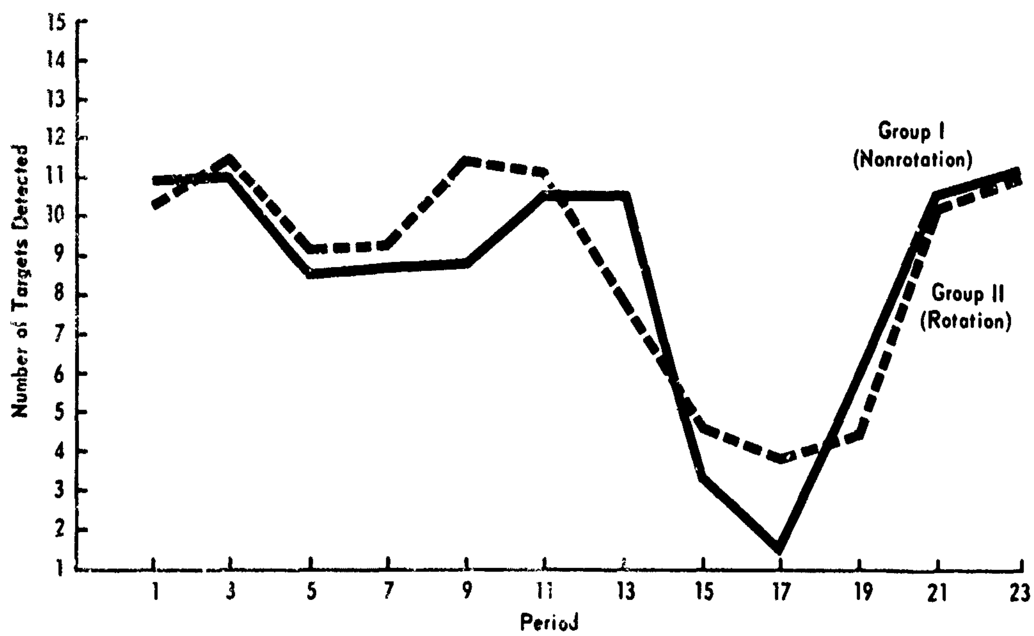

Figure 3

Study 2: Field

Thirty tank crews in a TOE unit participated in the field study, 20 experimental and 10 control crews.

Tests were constructed with which to compare performance between experimental and control crews on five basic types of activities found in armored combat—gunnery, surveillance, communications, driving, and maintenance. Because of the requirement that the test results be readily applicable to actual combat situations, the performance test situations were made as realistic as possible within the restrictions of personnel safety and equipment care.

A 48-hour field problem was designed as a context for the performance test. The problem was a day and night tactical situation that included offensive, defensive, and retrograde movement. Repeated measures of each performance test were inserted into the problem at 12-hour intervals.

For the experimental group the problem was conducted as a 48-hour continuous exercise, with no provision for sleep or rest. For the control group the problem was conducted according to a 12-hour work and 24-hour rest cycle (Figure 4).

The distance traveled by the tanks through one 12-hour circuit of the problem course was 35.7 miles. Of this distance, 24.6 miles consisted of travel on secondary roads and 11.1 miles were cross-country.

Work/Rest Schedule for Study 2: Field

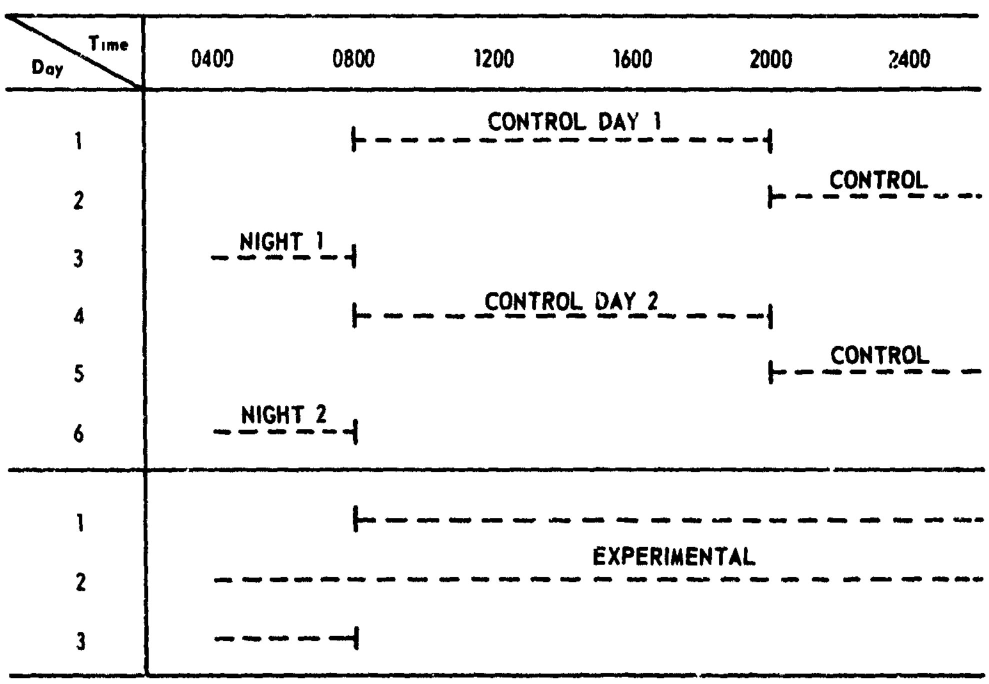

Figure 4

Thus, the total distance traveled during 48 hours was approximately 143 miles.

The results of this study provide some interesting information concerning tank crew endurance, tank crew training requirements and, more generally, the possible utility of laboratory studies for predicting actual job performance in similar situations.

Briefly, few performance decrements occurred that could be attributed to long-term operation. Table 2 indicates that some differences between

Table 2

Results of Field Study[a]

Task	Score Control Group (C)	Time Experimental Group (X)
Radio Telephone Procedure	C > X	
Maintenance	C > X	
Slalom	C > X*	C > X
Minefield	C = X	C = X
Log	C = X	C < X*
Ditch	C > X*	C > X*
Moving Surveillance	C > X*	
Passive Surveillance	C > X	C < X*
Moving Coaxial–Stationary Target	C = X	
Caliber 50–Moving Target	C = X	C = X
Main Gun–Stationary Target	C = X	C < X
Main Gun–Moving Target	C = X	C = X

[a]* indicates that the difference is significant at the .05 level or better.

the control and experimental groups did appear in those tasks requiring driving skill or surveillance. However, further analysis failed to show a trend in the differences that would indicate that they were due to progressive increases in fatigue resulting from continuous operation. Thus, the differences found between the two groups were more likely due to skill differences existing before initiation of the study.

With regard to the level of skill demonstrated, all crews showed surprisingly low levels of proficiency in tank gunnery, surveillance, and operation of searchlights and night vision devices. Group averages were so low in some skills that analysis of possible decrements could not be completed. This result may be due in part to the present high turnover rate in tank crews, but it also suggests a need for more effective methods for developing and maintaining crew proficiency within the using units.

Finally, while those differences found were in the driving and surveillance skills tested in the laboratory, they did not even approach the magnitude suggested by the laboratory results. Obviously subject motivation is an important and confounding variable. Also, it would

appear that the usual laboratory situation requiring continuous performance of a single task does not sufficiently duplicate the job situation where many tasks must be performed, any one of which occurs only periodically. Thus, we might well question the continuing use of standard tasks in present laboratory situations to predict job performance in real world situations. Since we cannot afford to repeatedly duplicate real world requirements, we are faced with a need to develop new tasks and situations, intermediate between the laboratory and the real world. These conditions need to be realistic enough to provide the motivation and job duties of the real world, but still simulated to the extent that they can be accomplished at less cost. Until such simulation is developed we might question the applicability of most laboratory results.

DISCUSSION

The results of the field study will have some practical consequences for military planning, but the fact that such a study was necessary and that application of the results is limited is perhaps of more interest than the results themselves. Clearly, we cannot continue to conduct costly, time-consuming field studies for each new condition or task that may be imposed by tactics and equipment, nor can we justify the lack of good, objective performance standards. Recent policy changes will eliminate most of these deficiencies. For example, the tactically oriented performance envelopes now being developed by U.S. Army Combat Developments Command (CDC) should provide a basis for deriving performance standards. The inclusion of human factors milestones in the CDC and U.S. Army Materiel Command (AMC) management models should provide human performance information during what are now purely hardware Engineering and Service Tests. Developmental studies of both tasks and conditions appear to be designed to provide more information that can be applied to real-life situations and thus to the solution of practical problems.

However, there is a long step between *should* and *will*. It seems we have been here before and suddenly we find ourselves back near the starting point. A number of studies are now being published which provide the model and demonstrate the feasibility of a systems approach to integrating developmental information on man, machine, and tactic. These studies show resulting cost savings and effectiveness increases (e.g., 8), but such approaches will succeed only if we develop the necessary methodology rather than becoming better "expertizers," and only if we, the Army's human factors agencies, continue to insist on their implementation.

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13. ABSTRACT

A laboratory study and a field study were conducted to obtain data on performance decrements on tank crew tasks during 48 hours of continuous combat operations, and to examine the degree of decrement in terms of its effect on tactical efficiency. Experience in the studies illustrates the need for increased efficiency in obtaining human factors information, demanded by the increasing complexity of military tactics and equipment.

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